MANUAL OF METHODS IN FISHERIES BIOLOGY

compiled by

T. LAEVASTU

Fascicule 9

Section 4. Research on fish stocks

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
ROME 1965

Printed in Italy

CONTENTS

SECTION 4. RESEARCH ON FISH STOCKS

4.0 INTRODUCTION

The whole object of research in fisheries biology is to obtain information on fish stocks, and consequently the focus must be on the work described in this Section. Work on the environment described in Sections 2 and 3, while essential, must be held in balance with that of this Section as described in Section 1.

Much of the work with which this Section deals is of a routine nature, and requires a detailed operational plan. This must be formulated by the research biologist at the commencement of the program. An operational plan for routine operations will take into careful consideration a number of statistical principles covering the choice of samples, the number of samples to be taken at each time and/or place and the size of each sample, as well as giving precise instructions as to techniques.

4.1 COLLECTION AND PRESERVATION OF MATERIAL

4.1.1 **Collecting with experimental gear**

Special gear is often used to collect samples of fish which are not normally caught with commercial gear, and small-scale commercial gear is used on research vessels in areas and seasons where no or little commercial fishing is done. Various plankton nets are used to catch fish eggs and larvae; and bottom egg nets, specially designed ring trawls and young fish trawls are used, each for its particular purpose. (See Section 3 for collection of plankton, benthos and nekton.)

Night-light fishing is sometimes done to collect positively phototactic fish and fish larvae. The light with a reflector, in a watertight cover, is submerged just below the surface, and a fine-meshed dip-net is swept back and forth through the water under the light.

Poisons are sometimes used to collect fish in shallow water, especially among reefs. The best poison for this purpose is ground cube root, 10 kg of which is sufficient to treat an area of about 10×10 meters if the current is slight and the depth does not exceed 2 meters. The poison should be thoroughly mixed with water in a bucket and then distributed on the surface, in midwater and on the bottom. The work should be done on slack low tide. Certain species will be affected by the poison almost immediately, while others may show no

Form 1. - Fishing log

(*a*) Vessel ..... (*b*) Journal No. ..... (*c*) Date .....

(*d*) Station No. ..... (*e*) Locality (area) .....

(*f*) Lat. ..... (*g*) Long. .....

---

1. Depth (of water) ..... 1.1 ..... 1.2 Nature of bottom .....

---

2. Sea ..... 2.1 Weather ..... 2.2 Wind ..... 2.3 ..... 2.4 Color ..... 2.5 Current ..... 2.6 Water temperature ..... 2.7 Depth of thermocline ..... 2.8 Air temperature ..... 2.9 Barometer .....

---

3. Wire out ..... 3.1 Gear, type ..... 3.2 ..... 3.3 Wire angle ..... 3.4 Speed of vessel ..... 3.5 Direction of haul .....

---

4. Time: 4.1 Gear-setting started ..... 4.2 Gear out ..... 4.3 Hauling in started ..... 4.4 Hauling in finished .....

---

5. Principal species retained and sizes ..... 5.1 Depth of capture ..... 5.2 How fish located ..... 5.3 Total catch ..... 5.4 Disregarded ..... 5.5 ..... 5.6 Principal species discarded and sizes ..... 5.7 Samples taken .....

---

6. Remarks .....

---

effects for several minutes. A diligent effort should be made to collect all fish killed by the treatment, regardless of size or variety. To find the very small specimens may require a thorough search of the bottom with the use of a face mask. The area searched for poisoned fish should be larger than the poisoned area, especially downstream of the poison.

Explosives are also used on certain occasions to ascertain the presence of fish or to catch and identify species when schools are sighted at the surface or on echo-sounders. The use of explosives for catching fish is forbidden in most countries and a special permission from authorities is necessary. In obtaining this permission the person(s) concerned must demonstrate ability in the use of explosives and knowledge of the risks. Depending on the circumstances, the collected material (fish) may be examined on the spot or samples may be taken for preservation. If any kind of fishing gear is used, the Fishing log must be filled in. For labeling the collections use may be made of the standard form of label described later.

Notes on Form 1. Fishing log

(*e*). Also state the name or general description (e.g. Wadge Bank).

1.2. If fishing for demersal fish state the type of bottom (and/or type of coast).

2.1. State code.

2.2. State direction and force, code.

2.3. State code.

2.4. Give in Forel scale.

2.5. Give direction (and speed if observed).

2.6. Also state the depths if observed at several depths with reversing thermometer.

2.7. As ascertained from BT data.

3.1. State type, dimension and essential mesh sizes, bait if used, etc. For night-light fishing give the depth and strength of light.

3.2/3.3 - 3.4/3.5. Give the amount of wire out, wire angle and speed and direction of vessel when trawling.

4. Give times so that actual hauling time can be computed.

5.2. E.g., echo-sounder, conventional ground, visual observation of schools, experimental run.

5.3. State the number of baskets, etc., and their approximate weights (include discarded).

5.4/5.6. Give all organisms present in the disregarded catch on commercial vessels and estimate their amount.

5.7. Indicate weather measurements made, samples preserved, etc.

6. E.g., damage to gear, behavior of fish, etc.

Form 2. - Gill net record

Location .....

Date ..... Depth of set .....

Time of set ..... Time lifted ..... Hours set .....

Temperature: Air ..... Water ..... Time .....

Weather: Present ..... Preceding .....

Water: Color ..... Turbidity .....

Type of bottom ..... Vegetation .....

Collector ..... Field collecting number .....

Species collected	Aver. length	Size range	Sex condition	Numbers

Form 3. - Seining record

Location .....

Date ..... Gear used ..... Length ..... Mesh .....

No. of hauls ..... Type of bottom .....

Aquatic vegetation - relative abundance .....

.....

Air temperature ..... Water temperature ..... Time .....

Turbidity ..... Field collection number .....

Collector .....

Species collected	Size range	Sexual condition	Numbers collected

Forms 2 and 3 are designed for recording the experimental catches in fresh water bodies. With some modifications these forms can also be used for marine work.

If the fish are collected by gill net, the mesh of the net should be entered, stating whether bar or stretched measure is used. Example: Gear 25 mm bar.

If the fish are collected by seine, the entry should be: S, then the length of the seine, then the mesh, stating whether bar or stretched measure is used. Example: Gear S-3-5 bar, which indicates the fish were taken in a three-meter long seine of five-millimeter bar measure mesh.

The mesh sizes are important in determining to what extent a given sample is representative of the total population. In reports the type of mesh measurement, bar or stretched, should always be stated.

4.1.2 Collecting from commercial catch

Commercial catches are the main source of material for population studies by way of an interpretation of the relation between catch and the population from which it is drawn. However, the subject of collecting from commercial catches in this sense (chiefly a matter of sampling) will be dealt with in another Manual in this series. Catches may be sorted by fishermen at sea, but nonetheless commercial catches at sea and in the market are a source of material for other parts of the program of fisheries biology. At sea the discarded part of the catch may be of considerable importance. Firstly, this part of the catch may consist of undersized fish, the study of which may furnish important information concerning recruitment and the prerecruit phase of the fishable stocks. Secondly, study of the catch of organisms of no economic importance may be necessary for an understanding of the ecology of the species of economic value.

Collecting from commercial catches, at sea or in the market, is undertaken according to the requirements of the biological inquiries in progress; the material collected will be treated as described in Sections 4.1.3 and 4.1.4. Careful note should always be kept of the date and place of collection and of any information obtained concerning the manner in which the organisms were caught, and the place and time of capture.

4.1.3 Collecting separate organs and tissues

Scales are used to determine age and the back computation of growth. The selection of fish from which to take scales depends on many considerations chiefly determined by the sampling requirements of the population studies. Special instructions should be prepared by the biologists to guide the field worker in this matter.

The areas from which scales generally are taken are shown in Figure 1, but the area varies from one group of species to another. Scales should be

taken from the side of the fish, avoiding the lateral line since this may have a very high percentage of regenerated scales and scales otherwise disturbed. Scales are taken from the anterior third of the body of herrings, above the lateral line or under the dorsal fin, and from flatfish from the eye side and most often from the middle of the body. If possible, the fish should be washed slightly to remove scales of other fishes that may have adhered to the body. From 10 to 25 scales are pulled out with forceps or a pocket knife and placed in small envelopes, each of which is marked with a log number or with data on the fish, such as species, length, weight, sampling place.

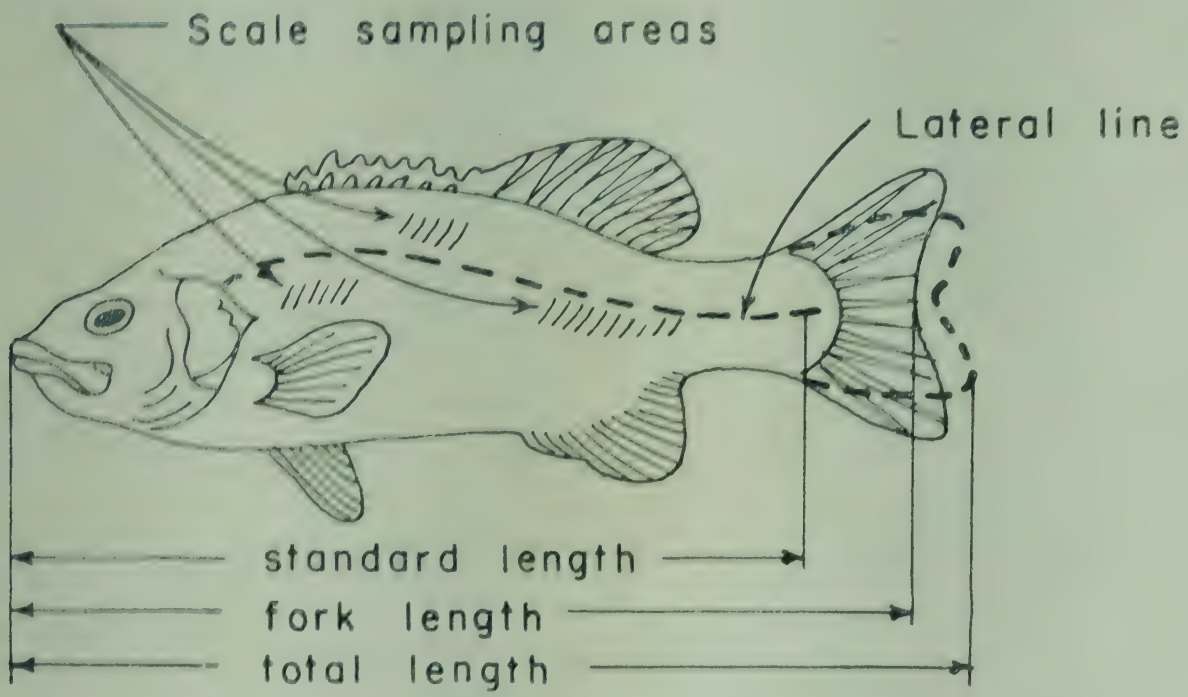

FIGURE 1. - Common fish measurements and areas of scale sampling (from Lagler)

Otoliths are sometimes used for age determination of fish since they also carry regular markings corresponding to events in the life of the fish. They are located in the head of the fish and are part of the auditory apparatus. They are extracted by cutting into the head of the fish and then withdrawing them with forceps. The manner of cutting into the head depends on the type of the fish and is determined only after some amount of experiment (see Figure 2).

Spines and rays also may carry regular markings and thus be useful for age determination. The selection of rays or spines to be removed for this purpose is a matter for determination by the biologists. The rays of the first branched arch are usually selected.

Vertebrae may be collected either for racial investigations or for age determination. In the latter case certain particular vertebrae are generally selected and would be indicated by the biologist. The vertebrae required for such studies should be preserved according to instructions provided by the biologist; in general they are kept in 60% alcohol. In the former case the

entire vertebral column may be required. Counting can sometimes be done at sea, but clear instructions must be given by the biologist, especially with regard to abnormal vertebrae.

Gonads. The examination of gonads to ascertain the state of maturity is usually done in the field. The gonads should also be weighed in fresh condition, because they change considerably when preserved. The counting

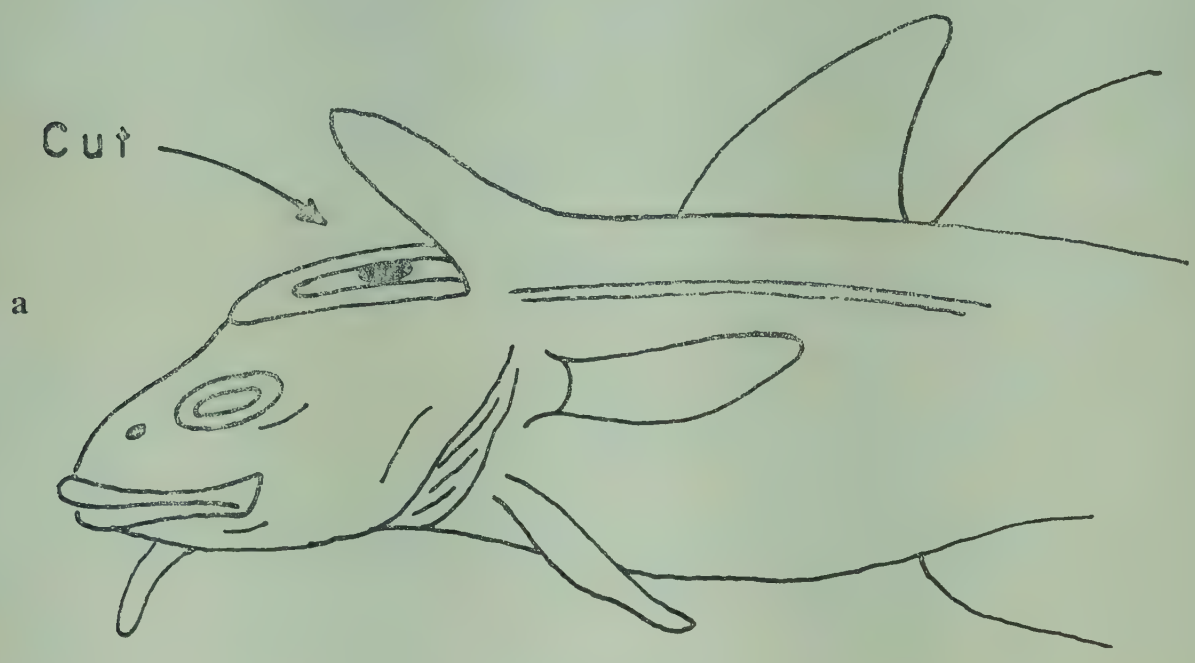

FIGURE 2. - (*a*) Cut for taking otoliths from *Gadus morrhua*

(*b*) Cut for taking otoliths from *Pleuronectes platessa*

of eggs can however be done on preserved material. The gonads are removed by careful opening of the ventral cavity and are preserved in 4% formalin, properly labeled with information concerning the size of fish, its condition, etc.

Stomach. Examination of fish stomachs or preservation of their contents should be done as soon as the fish arrive on board because the enzymes continue to act on food in the stomach after the death of the fish. Stomachs should be collected at random whether empty or full, and should be preserved in 8% formaldehyde in order to stop digestion at once.

Gill-rakers may have to be collected for racial studies. They are obtained by taking the entire branchial arch, and should be preserved in 60% alcohol.

4.1.4 **Preservation of biological specimens**

Whole fish. A 4% solution of formalin is generally used for preservation. This is made by diluting one part of concentrated formalin (37-40%) with 9 parts of water. This must be neutralized with 1 g $CaCO_3$ per liter. The volume of material to be preserved should never exceed that of the preserving liquid. Fish less than 10 cm long should be immersed completely in the formalin. Fish 10-30 cm long should have several narrow cuts made in the abdominal wall a little to one side of the midventral line. Fish longer than 30 cm should be injected with undiluted formalin in several places and the belly should be slit in several places.

All preserved specimens should be properly labeled. The colors of the fresh specimens should be recorded.

Scales are usually kept dry in envelopes. They can also be preserved for shorter times (a week or two) in water in small tubes.

Otoliths are kept dry in envelopes or on special otolith boards. Alcohol (60%) can also be used for preserving otoliths of some species; such storage facilitates the reading of them.

Vertebrae are usually preserved in 60% alcohol.

Gonads are usually not preserved, but if preservation is necessary, it can be done in 4% formalin. However when egg counting is to be undertaken the eggs are best preserved in Gilson's fluid, of which the formula is:

100 ml 60% alcohol

880 ml water

15 ml 80% nitric acid

9 ml glacial acetic acid

Stomach is preserved in 8% formalin.

4.2 FIELD IDENTIFICATION

A field officer should familiarize himself with the main species of fish and other organisms in the area in which he is working and form a general idea of the composition of the fauna of his area. Acquaintance with the main species should be such that there should be no errors in identification of them and that any special forms, in the sense of racial differentiation or malformation from disease or other cause, should be readily noted. As to species of less importance and other elements of the fauna, collections and observations will be made as required by the program. Although this is not the place for an account of taxonomic procedures, or for keys for different groups of organisms, Figure 3 is included for ready reference and shows the principal external features to which reference is made in descriptions of fish. For detailed taxonomic work reference should be made to standard texts.

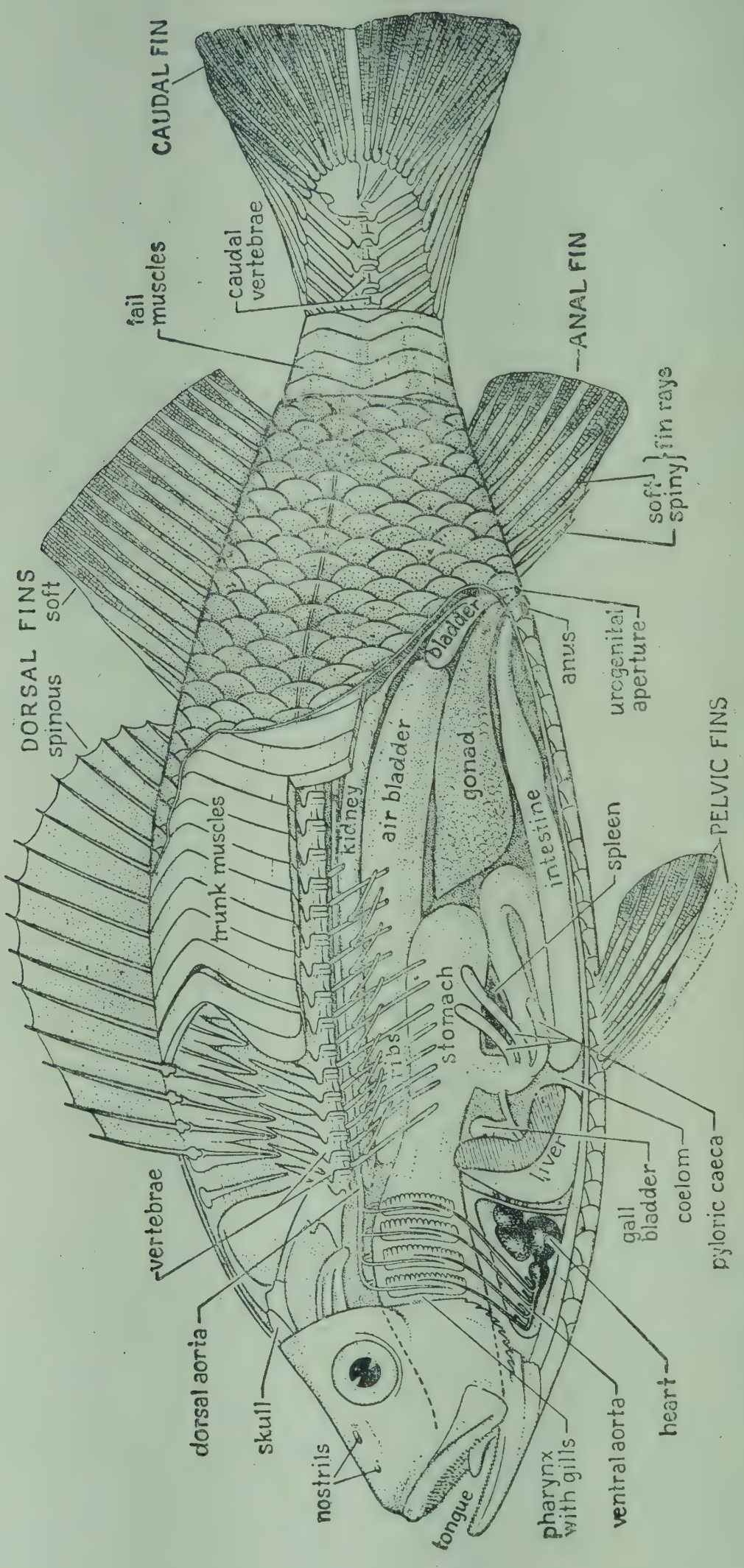

FIGURE 3. - General structure and morphological features of a fish. (T.I. Storer. *General zoo.ogy*. New York, McGraw Hill.)

4.3 OBSERVATIONS ON BEHAVIOR AND DISTRIBUTION

Although direct observation of the behavior of fish in its environment has become more practicable, most conclusions on fish behavior are drawn from a variety of observations on the occurrence of fish and prevailing environmental conditions. Certain types of observations should be made systematically in the course of field work, and must be carefully recorded.

(*a*) Schools of fish observed close to the surface must always be recorded, giving the exact position, the estimation of the size of the school, its probable species, the behavior (such as jumping, etc.) and the direction of the movement. Furthermore, the prevailing sea conditions must be recorded simultaneously (state of the sea, color, etc.).

(*b*) The direction of approach of fish to gill nets should be recorded, together with the direction of the layed net and the direction of the currents.

(*c*) The depth occurrence of the fish in gill nets and on trolled longlines should be recorded if possible (e.g., if fish are caught in gill nets mainly on the upper or lower part, etc.).

(*d*) Response of pelagic fish to bait should be recorded.

(*e*) Degree of liveliness of fish caught with trawls and traps should be noted if differing from normal. Also other abnormal conditions of catch could be noted (e.g., abnormally high vomiting, etc.).

Good information can be obtained from echo-sounder (and asdic) observations, and precise correlation of location and behavior with various environmental features can be obtained.

4.4 MEASUREMENTS AND COUNTS ON FISH AND SHELLFISH

Measuring linear dimensions of whole or parts of fish is probably the most widely used technique in fisheries biology studies. Such observations are made with special measuring boards, tapes and calipers. Measurements are usually but not always taken along straight lines. Counts of numbers of fin rays, etc., are less often made in the field and are only briefly mentioned here.

4.4.1 **Length measurements of fish**

The length distributions of fish in samples taken on markets or on research or commercial vessels give the simplest index of the composition of the stock from which the catches are being taken. The choice of which of several possible measures of the over-all length of the fish is to be used for routine purposes depends on many factors, but primarily on the ease and speed with which the measurement can be taken under the given working conditions,

and on the state of the fish (e.g., on whether the caudal fins are usually broken by the time of landing).

It is usually possible to establish a single basic (standardized) length dimension to be used within a particular sampling program. A basic length may even be adopted for use in several programs of research on the same species or group of species of fish (e.g., internationally).

The choice of measurements taken to estimate the size composition of whole catches or landings is considered quite separately from that of the attributes for the purpose of distinguishing species, races, or other subdivisions of stocks. For the former purpose the desirable criteria, apart from unambiguous definition and clear recognition, are:

1. Ease and speed of measurement with simple equipment under field conditions.
2. Existence of a close relation with weight of fish.
3. Repeatability by the same or different observers with high consistency of results.
4. Existing practice, especially with regard to the accumulation of past data.
5. Consistency with measurements which might be made on other fish species at the same time.
6. Consistency with measurements of similar fishes being made elsewhere; probably in that order of importance.

Fulfillment of the third criterion clearly depends on the precision aimed at, and both the first and third are related to the design of the measuring board. The first three criteria are amenable to experimental test.

Some attention has recently been given to studies of personal error and precision in measurement by comparing observations by different observers. If length is normally distibuted there is no bias in the mean, but the variance is increased by observed error; if distributions are rectangular or J shaped (exponential) considerable biases are introduced. However, in comparison with sampling variance, these biases are not usually regarded as being too serious.

Personal errors can, nevertheless, be significant, but they can be minimized by paying attention to the conditions of measuring. Once a basic dimension has been chosen which is not such as will clearly invite errors and inaccuracies in measurement, the instrument to be used can be designed to facilitate that measurement.

Very often, however, differing conditions of sampling and different states of the fish make it undesirable, or even impossible to measure always the same dimension; in such cases a reference length may be chosen to which all other measurements, including the basic length, can be converted if suitable conversion factors have been determined.

The definitions of length dimension given later in this Section apply also to measurements made more for comparative morphometric studies. Such detailed and precise measurements are frequently made in the laboratory rather than in the field.

4.4.1.1 Method of measuring

Over-all length measurements are usually made with the fish lying on its right side, snout to the left, on a measuring board consisting essentially of a wooden or metal base carrying a center scale and having a headpiece (nose block) against which the snout is gently pressed. The mouth is closed, the fish body and tail straightened along the midline and the reading taken from the scale. An attempt is usually made to measure the whole fish in the fresh, wet condition (that is as near to the relaxed live condition as possible); if *rigor mortis* has set in the fish should be gently flexed just before measuring. In certain circumstances (e.g., during tagging experiments) fish may be measured alive; it may then be necessary to take special steps, such as injection of narcotics, to relax the fish during handling.

Rays and other dorso-ventrally flattened fish may be measured while lying straight on their ventral surfaces; the standardized linear dimension of rays is indeed often the disk width rather than over-all length.

Large, fat fish present difficulties. Their lengths may be measured with calipers or from point to point along the body surface with a tape.

Commonly, measuring is done by observers working in pairs, one of whom places the fish on the board and reads the scale, the other records the measurements called out by the first. Various devices have been used to permit measuring by a lone observer. The surface of a part of the measuring board may be divided parallel with the central scale and be of such a texture that erasable marks may be made with a pencil, etc.; or strips of paper may be pinned along the board. In one type of board ruled paper, protected by a covering of tinfoil or of cellophane or similar transparent material, forms the scale, and is pierced with a needle in the appropriate place at each measurement. The board itself may be dispensed with, and a narrow celluloid strip used on any flat surface (e.g., the deck of the ship). It is pierced at each measurement, and the lengths are read against a scale on returning to the laboratory. Devices recently developed use click-counters, arranged in a row along the measuring board, one for each scale interval. From these the length-frequency distribution of a measured sample can be read directly. Use of a simple measuring board, the observations being dictated into a portable tape recorder, has been tried successfully and there have been proposals for various types of automatic or semiautomatic measuring instruments.

4.4.1.2 Measuring damaged fish

Suppose that total length is the basic dimension chosen. If an occasional fish in a sample has its caudal fin damaged, it should not be discarded but its total length should be estimated by comparison with another fish of about the same size, to avoid possible bias arising because damaged fish tend to be larger or smaller than the average.

If whole samples or large proportions of specimens are damaged, another convenient dimension must be measured, for which there is available a con-

version chart based on the calculated regression of total length on that dimension. This may cause a problem in grouping the observations, which is simplified if such measurements are made to millimeter accuracy, converted to total length individually or by millimeter groups, and the calculated total lengths grouped in the normal way. Choice of the other dimension to measure is largely a matter of convenience.

4.4.1.3 Measuring processed fish

Dimensionally the most stable part of specimens of many fish species when they are being dried is probably the head. The head length, however, often varies allometrically with total length and conversion then has to be made by using a chart or table based on the regression of total length (or its logarithm) on head length (or its logarithm).

Conversion keys must be applied only to the stock for which they were determined and should be checked periodically to see whether the regression has changed. If it is found that it does change, it will be necessary to determine the keys anew each season, unless some additional factors are found which permit use of the same key or set of keys. The most likely cause of change in the keys is the probable dependence of the regression used on the growth rate of the fish, it commonly being found that the relative length of the head of a fast growing fish is less than that of a slowly growing fish of the same size. This relation is reflected in the condition factor, and thus usually in the body depth, which tends to be greater in faster growing fish. Body depth and head depth are probably closely related, or at least vary together. This suggests a means of using two measurements such as head depth and head length to estimate total length of dried fish.

In other situations where the recommended standard is not for any reason adopted, conversion tables or charts should be drawn up as described above, from special experimental observations.

A particular question to which careful attention should be paid is the degree of freshness and wetness of the measured specimens. It is common knowledge that fish will shrink rapidly on drying. Normally, when measurements are made on fishing craft or on markets at the time of unloading this problem will not arise, but if samples are taken away for later observation, a means of conversion of measurements to fresh, wet condition may have to be employed.

4.4.1.4 Units of measurement, precision and group size

It has been recommended that the metric system be adopted universally for all scientific measurements relating to the assessment of fish stocks.

The precision with which the results of measurement are stated should be related to, and certainly not higher than, the accuracy with which the meas-

urements are or can in practice be made. This accuracy is not usually more than 99 percent, so that measurements of fish over 10 cm long should not normally be quoted to millimeter precision. The unit interval on the measuring scale is preferably related to the agreed precision of the measurements to be made.

For fish ranging from about 10 to 50 cm in length, quarter- or half-centimeter intervals may be satisfactory.

Choice of the class interval is a matter of judgment. For convenience and brevity it is desirable to make the class interval as large as possible, subject to the condition that it is also desirable to be able to treat all values assigned to any one class, without serious error, as if they were equal to the midvalue of the class interval. These conditions will usually be fulfilled if the interval be so chosen that the total number of classes lies between 15 and 25.

Class limits may be set so that either the limits or the midpoints of the class intervals are convenient round numbers. It is a general principle of measuring that class limits should correspond with a scale mark on the instrument, and the scale numbers corresponding with the marks should be convenient round numbers. Given these criteria, there are two ways of reading the scale.

1. To the nearest scale mark.

2. To the next scale mark above or below.

The first method is usually not good because judgment of which is the nearest mark takes more time than judgment whether a mark is reached or not. It is more subjective and, in the case of fish measuring as opposed to the movement of a needle across a dial, it can be biased by the asymmetry of the display of fish and scale. This can readily be demonstrated experimentally.

If measurements are made to the scale unit above or below with a normal measuring board, the intervals have limits at multiples of whole units and midpoints at half units. If the scale zero is offset by half a scale unit from the headpiece (see Figure 4) the resulting classes have whole-unit midpoints and half-unit limits, and the method is equivalent to unbiased reading to the nearest scale unit with a normal board.

Offset boards have some disadvantages. It may be necessary to group classes in different ways for different purposes, and this cannot conveniently be done if the class midpoints, rather than the limits, are whole-unit multiples. An offset board also cannot be used easily as a scale for other purposes, unless it has a removable headpiece block one half-unit thick. Such an arrangement is undesirable as it unnecessarily complicates the equipment; the removable piece can be mislaid or errors made by the observer not noticing whether it is fitted at the time that measurements are taken.

The differences between measurements to the nearest unit, or to that above or below, may be conveniently shown by considering the limits and midpoints of, say, the 20-cm group (supposed using ½-cm grouping), the 1-mm groups which make up the ½-cm group, and the 1-cm groups obtained by adding two ½-cm groups.

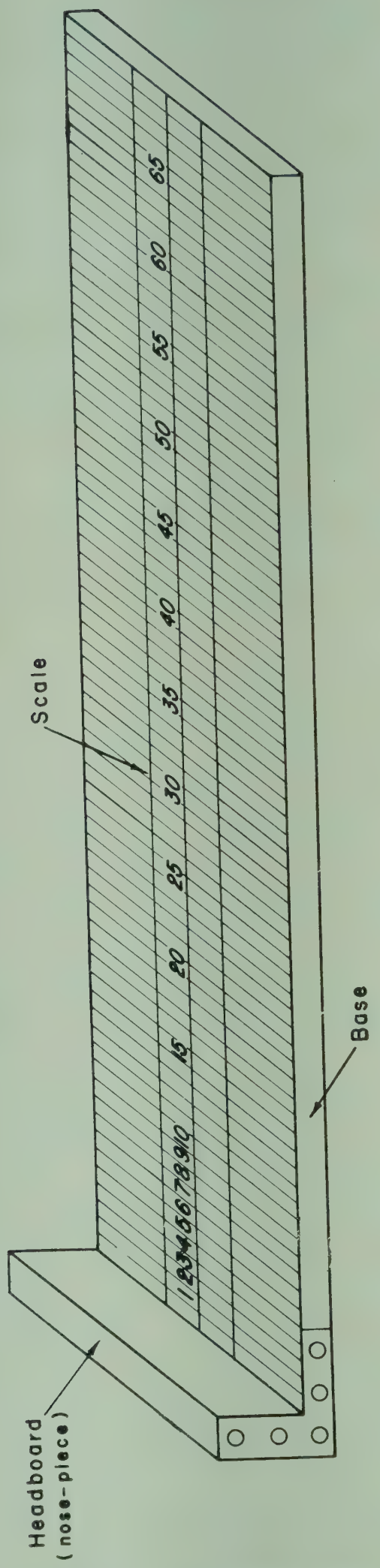

FIGURE 3. - Measuring board

Method of grouping	*Nearest*	*Next above*	*Next below*
Limits of 20-cm group (by ½ cm)	19.75-20.25	19.50-20.00	20.00-20.50
Midpoint of 20-cm group	20.00	19.75	20.25
Constituent 1-mm groups of 20-cm group	198,199,200, 201,202	196,197,198, 199,200	200,201,202, 203,204
Limits of 20-cm group (by 1 cm)	19.5-20.5	19.00-20.00	20.00-21.00
Corresponding ½-cm groups	None	19.5-20	20-20.5

It should be noted firstly that data given to the nearest unit cannot be combined for groups equal to an even number of the original units, e.g., 1 mm to 5 mm is possible, ½ cm to 1 cm is not.

Secondly, combination of data given to the unit below is more obvious to the eye than for data given to the unit above, e.g., classing 201 as 20 is quicker than classing 197 as 20. Again, class intervals are customarily designated by their lower limits; someone aged 35 years 9 months is referred to as 35 rather than as 36. Several arguments thus weigh against measuring to the nearest unit, whether or not this is achieved with the aid of an offset scale.

There is commonly some preference for reading the scale to the unit below rather than to the unit above, but this decision must depend on the design of the measuring board in relation to the dimension chosen for measurement. Thus for fork length, reading errors are minimized if the scale numbers run down the center line of the board. The first number visible beyond the fish is therefore the one read and entered on the recording sheet, and would be the scale mark above. For dorsal extreme length or body length, for both of which the scale numbers would most conveniently lie above the center line, there seems to be no particular advantage in reading to the unit above or below.

We have seen that there are advantages in designating class intervals by their lower rather than by their upper limits. If, as with fork length, there were some small advantages in reading to the scale unit above but designating the interval by the lower limit, then a scale offset by one whole unit can be used to achieve both ends; but for extreme length it is simpler to read a normal scale to the unit below.

4.4.1.5 Design of measuring boards

The special requirements have already been outlined above. Here are given some general principles of design, illustrated with reference to the requirements

for field measurements of total length of clupeoids, carangids and scombroids not exceeding 40 cm. For this purpose a half-meter scale would usually be adequate. The board would, however, probably often be used to measure other kinds of fish, and then an extension piece, or hinged section would permit measurements up to one meter.

If measures of standard (body) length and other dimensions than over-all length are to be measured, it may be necessary to fit a sliding cursor carrying a wire which passes over the fish when it is lying on the board. Such boards also sometimes have a mirror on the base; if the measurement is read with the eye in such a position that the wire and its mirror image coincide, parallax error is avoided. Devices of this kind are more often used in the laboratory for morphometric studies than for routine observations in the field.

The basic data required for the rational design of a scale comprise: (1) the total range of the variable to be indicated, (2) the maximum accuracy and sensitivity required in transfer of information, and (3) the maximum equipment and operational error in terms of bias and variation, the latter in this case being determined by repeated observation of the same fish. When these are known, the scale size, range and number of divisions, can be decided. If there are too few divisions there will be unnecessary loss of information; if too many, time is wasted and a spurious accuracy obtained.

4.4.1.6 Scale divisions

Commonly, for fish of the size range in our example routine measurements are to be made in ½-cm units and special measurements to millimeter units. If the same board is to be used for both kinds of work, and it is convenient if this is possible, then the major scale marks should be a ½ cm apart, with intermediate strokes 1 mm apart. The strokes at whole-centimeter and half-centimeter intervals should be identical, to avoid bias. For the same reason it may be desirable to have a scale number corresponding with each major mark, though this may not be practicable if the numbers are to be engraved the correct size (see below). (Visually, the optimum distance between numbered scale markings is 1 to 2 cm; between unnumbered markings not less than 1 mm.)

Scale numbers and marking strokes should contrast well in tone and color with the scale face. Scale numbers will naturally increase from left to right as the fish is to be measured lying on its right side, and normal visual expectation is that the scale will run in this direction.

There should be some indication, by large numbers or partially thickened lines, of the points which are multiples of 10 cm and perhaps also of the multiples of 5 cm. The scale will then conform with the general principle that all engraved lines and numbers should increase in units, fives or their decimal equivalents.

The ½-cm markings are conveniently continued right across the board which would normally be about 12 cm wide. There should be a median longitudinal line the full length of the board. and the scale numbers should be set

about 2 mm above it, the millimeter marks being on the median line or just above it.

If measurements are to be made to the unit above or below with a normal scale the zero of the scale should be level with the headpiece of the board, which would be about 5 cm high.

The following are the recommended dimensions, in mm, of engraved numbers and scale marks to be read at normal viewing distance of up to 1 m.

Numbers	Minor	Intermediate	Major
Height	2.3	3.1	4.7
Width or stroke thickness	0.4	0.5	0.6
Scale strokes			
Length	2.3	3.9	5.5
Width	0.4	0.5	0.6

With a dark character on a light background a height to stroke thickness ratio of about 6:1 is best; with a light character on dark, a ratio of 10:1 is better. In general the optimum height to width ratio of the character itself is 3:2.

It is sometimes found useful to have a beveled edge to the base of the board, to prevent fish sliding off; under certain conditions, however, this is a hindrance rather than an advantage. The board can usefully have a carrying handle, and if it has attached surfaces in which measurements can be written by a lone observer, it should have a hole or eye for the attachment of a pencil by string, or similar arrangement.

4.4.1.7 Definitions of linear measurements

Over-all lengths may be measured from the snout (U, the position of the maxillary symphysis) or from the tip of the lower jaw (L, the mandibular symphysis). Measurements from L are taken with the mouth closed. If the lower jaw projects much beyond the upper jaw, measurement from S may necessitate provision of a special "stepped" nose piece on the measuring board.

There are three main over-all length measures in common use. These are roughly illustrated in Figure 1. Standard length, the standard dimension of taxonomy, is properly measured from U to the tip of the hypural bone (urostyle). In practice it may be measured to some external feature more or less corresponding with the latter point; this would vary from one species to another but examples are the last scale, or point of silvering, to edge of skin pigment (determined by scraping away the posterior scales), to tip of fleshy peduncle or to the keel. Fork length is measured from U or L to the cartilaginous tip of the shortest, or median, caudal fin ray. It may be difficult

to measure if the tail is split. Total length is measured from U or L, to the tips of longest caudal fin rays, in several possible ways. Measurement may be taken to the tip of the dorsal lobe, of the ventral lobe, or of the longer of the two, or some average of them both (such as to the midpoint of a line joining the two tips or to the point where such a line crosses the median longitudinal axis).

The tail fin may be in the extended position to give normal (total) length or the tips of one or both caudal lobes may be drawn to the longitudinal axis extreme (total) length. Sometimes total length measurements are made with the caudal lobes partially drawn together so that their outer edges are parallel to each other and to the axis. It is therefore clear that precise instructions must be given as to the dimension to be measured and the mode of measuring. In particular, if a normal length is the chosen dimension, it is necessary to standardize the procedure of laying the fish on the board. A common method is to place the head of the fish against the nose piece with the right hand, hold the fish in position with the left hand, and use the right hand to straighten the body of the fish and extend its tail with a single stroking movement.

There follow useful sets of notations and definitions for positions and linear measurement, which are applicable to many types of fish; they are illustrated with reference to a scombroid in Figure 5.

Positions are defined as on the left side of the fish unless stated to the contrary. When side-to-side comparisons are being made, or if necessary for other reasons, distinguish by prefixing " r " or " g " (right or greater) to the notation (or term). This rule may be especially applicable to the dimensions Ph and Vh.

Lower-case letters are used by themselves in the notation where the dimension is not defined with respect to two fixed points, e.g., q, b, g. Otherwise d stands for " diameter, " h for " depth, " and g for " greatest. "

Over-all length measurements are always made between perpendiculars along median longitudinal body axis, from L or U with mouth closed. Measurement is understood to be from L unless otherwise specified, thus e.g., UX Upper (or " maxillary ") dorsal extreme length.

Longitudinal measurements other than over-all length are also often made between perpendiculars, using a measuring board with, for example, a sliding cursor. When they are made radially from point U, using calipers as is recommended, the symbol for the dimension should be in parentheses, and the name followed by the qualifying term " direct. " Point-to-point measurements are sometimes made on big fish, e.g., tunas, by tapes. They would be indicated by the word " surface; " they are not generally recommended. The term " radial " is not recommended to be applied to point-to-point measurements as it invites confusion with fin-ray counts.

All measurements listed from LX to LM and also their " Upper " equivalents are grouped under the general name Total length, LT. LM has also been called " bilobular length " and " total auxiliary length. " It is rather difficult to measure.

The word " extreme " is used in LX, LX' and LX" instead of " maximum " to avoid confusion with the asymptotic size referred to in growth studies. " Great-

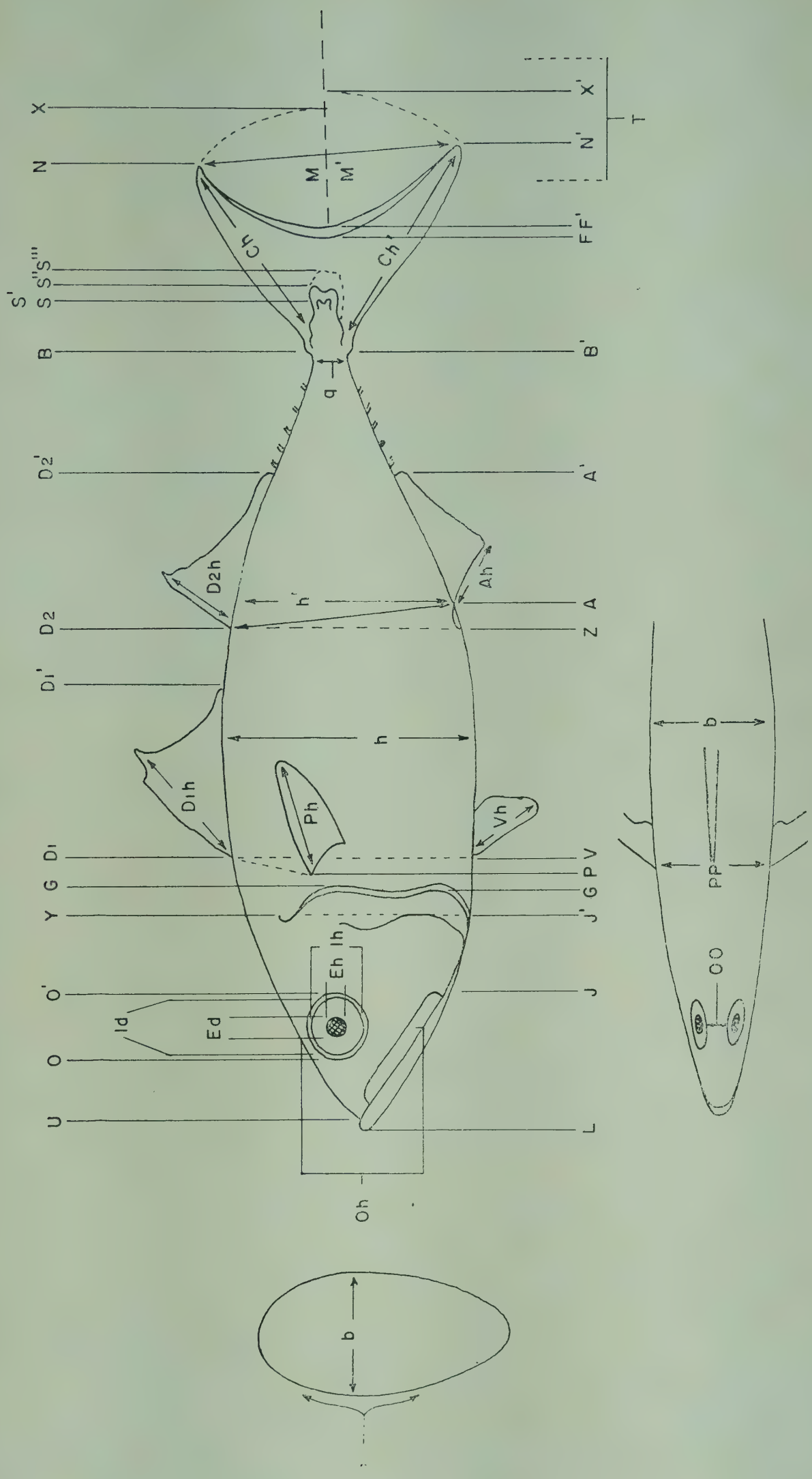

FIGURE 5. - Body measurements of fish
(see text for definitions and nomenclature)

est" is a possible alternative to "extreme" but invites confusion with "greater" for which a suitable alternative cannot be found.

LF and LF' have also been called "median length" or "midcaudal length." The term "standard length" has on occasion been applied to the distance LB as well as to the LS series; this usage is not recommended. It is not known that the ventral body length, LB', has ever been used in practice.

"Depth" is used in terms from Oh to q instead of the alternative "height" to avoid possible confusion with fin heights as measured by length of rays. The ambiguous term "width" is not recommended. Again "width" is not recommended as an alternative to "breadth" in terms for PP and b but "thickness" would be suitable.

Pectoral and ventral fins, Ph and Vh, are usually measured in their folded positions opposed to body size (to keep rays straight) from foremost visible point of insertion to the distal tip of the membranous edge.

In measurements of eyes the limits of Id, Ih and Ig are the boundary of the iris with the black tissue. Ig and Eg are not necessarily equivalent to either Id or Ih, Ed or Eh respectively.

The method of measuring g, in particular the permissible degree of constriction of the belly, remains to be defined precisely. Other girth measurements might be more consistent and perhaps related to conditions relevant to selectivity problems, e.g., if taken level with Y or D1. An appropriate notation could be gY, gD1, etc.

Spread caudal distance NN' has been used for tunas.

In various types of fishes certain of the dimensions listed may be virtually indistinguishable. Thus in the mackerel *Rastrelliger* LM = LM', LS = LS'', UJ = UO', UY = UJ', and so on.

Definitions of position

U	Maxillary symphysis
L	Mandibular symphysis
OO	Anterior edge of orbit
O'	Posterior edge of orbit
J	Posterior edge of mandible (buccal commissure)
Y	Gill-cover notch
G	Posterior bony edge of operculum
G'	Posterior membranous edge of gill cover
P	Anterior point of insertion of first pectoral fin ray
D1	Insertion of anterior dorsal (intersection of anterior margin of first dorsal spine, fin held erect, with the contour of the back)
D1'	Position of last ray of anterior dorsal
D2	Insertion of first ray of posterior dorsal
D2'	Position of last ray of posterior dorsal
Z	Anterior edge of cloaca
A	Insertion of first anal fin ray
A'	Position of last anal fin ray

B	Insertion of dorsall obe of caudal fin
S	Posterior tip of urostyle (forward protuberance of hypural blade)
S'	Posterior edge of fleshy peduncle or of pigmented zone
S''	Point of upper caudal keel
S'''	Posterior limit of silvering (either last scale of the lateral line or the posterior limit zone of the scale covered by the peduncle)
F	Cartilaginous tip of shortest (median) caudal ray
F'	Membranous edge of caudal fin at fork
N	Distal tip of the longest dorsal caudal fin ray, lobe normally extended
N'	Distal tip of the longest ventral caudal fin ray, lobe normally extended
M	Point where line NN' intersects median longitudinal axis
M'	Midpoint of line NN'
X	Distal tip of longest dorsal caudal fin ray, with the lobe brought to the median longitudinal axis
X'	Distal tip of longest ventral caudal fin ray, with the lobe brought to the median longitudinal axis

Over-all length measurements

LT and UT	Total length (any extreme or normal length)
LX	Dorsal extreme length
LX'	Ventral extreme length
LX''	Greater extreme length (LX or LX', whichever is greater)
LN	Dorsal normal length
LN'	Ventral normal length
LN''	Greater normal length (LN or LN', whichever is greater)
LM	Median normal length
LM'	Mean normal length
LF	Midcaudal length
LF'	Fork length
LS	Standard length to urostyle (or to some external feature corresponding with it, see commentary)
LS'	Standard length to peduncle (or to pigment under scales)
LS''	Standard length to keel
LS'''	Standard length to silvering
LB	(Dorsal) Body length

Other longitudinal measurements

UJ	Maxillary sheath length
LJ'	Mandibular length
UO	Snout length
UY	Upper head length
LG	Opercular head length
LG'	Gill-cover head length

Lg	Greatest head length
OO'	Orbital diameter
Id	Longitudinal iris diameter (cf. Ih and Ig)
Ed	Longitudinal pupil diameter (cf. Eh and Eg)
O'Y	Postorbital distance
UD1	Preanterior dorsal distance
UP	Prepectoral distance
UV	Preventral distance
UD2	Preposterior dorsal distance
D1D1'	Anterior dorsal fin base length
D2D2'	Posterior dorsal fin base length
UA	Preanal distance
AA'	Anal fin base length

Vertical measurements (perpendicular unless otherwise stated)

Oh	Orbital depth (from orbital crest to lower edge of maxillary, passing over middle of pupil)
Ih	Perpendicular iris diameter
Eh	Perpendicular pupil diameter
YJ'	Head depth
D1P	Back depth (oblique)
D1V	Anterior dorsal depth (or dorsoventral depth)
h	Greatest depth
D2Z	Posterior dorsal depth
D2A	Dorsoanal depth (slightly oblique)
h'	Perpendicular anal depth
q	(Least) peduncle depth

Lateral measurements

PP	Pectoral breadth
b	Greatest breadth
OO	Interorbital distance (at level of pupil centers)

Other measurements

D1h	Anterior dorsal height (distance from insertion to tip of longest spine)
D2h	Posterior dorsal height (distance from insertion to tip of longest spine)
Ph	Pectoral fin length
Vh	Ventral fin length
Ah	Anal fin height
Ch	Dorsal caudal fin length
Ch'	Ventral caudal fin length

Ch"	Greater caudal fin length
Ig	Greatest iris diameter
Eg	Greatest pupil diameter
g	Greatest girth
VV	Length of interventral flap
NN'	Spread caudal distance

Skeletal dimensions

Ax	Axial length (anterior face of vertebra 1 to tip of urostyle)
Sk	Skull length (maxillary symphysis to posterior occipital boundary)
An	Anatomical length (= Ax + Sk)

4.4.2 **Length measurement of mollusks**

1. *Bivalves*

The measurements are shown in Figure 6.

(i) *Length of shell.* The greatest measurement in an anteroposterior direction; this is usually approximately parallel with the axis of the hinge.

(ii) *Width of the shell.* The greatest measurement in a dorsoventral direction; this is usually approximately at right angles to the axis of the hinge and approximately at right angles to the length measurement.

In shells with very irregular shapes such as the oyster, the length is not always greater than the width.

(iii) *Depth of the shell.* The greatest measurement at right angles to the plane of the above two measurements.

Measurements are made with calipers or measuring boards.

Reference: Loosanoff, V.L. and Nomejko, C.A. (1949) Growth of oysters, O. *virginica* during different months. *Biol. Bull. Woods Hole*, 97 (1): 82-94.

2. *Gastropods*

The usual measurement is the length or height of the shell, being the maximum measurement from the tip of the whorl to the tip of the shell. (See Figure 6.)

Reference: Warren, P. J. (1958) A device for rapid single-handed measurement of shellfish. *J. Cons. int. Explor. Mer*, 23 (3): 440-442.

4.4.3 **Measurement of crustaceans**

Lobsters, crawfish, shrimps, prawns. The length of the carapace is the minimum length by calipers from the inside of the eye socket to the posterior margin of the carapace. In some cases (lobsters) the measurement will be parallel with the midline, in others (some shrimps) it will be from the eye socket to the center of the dorsal margin of the carapace.

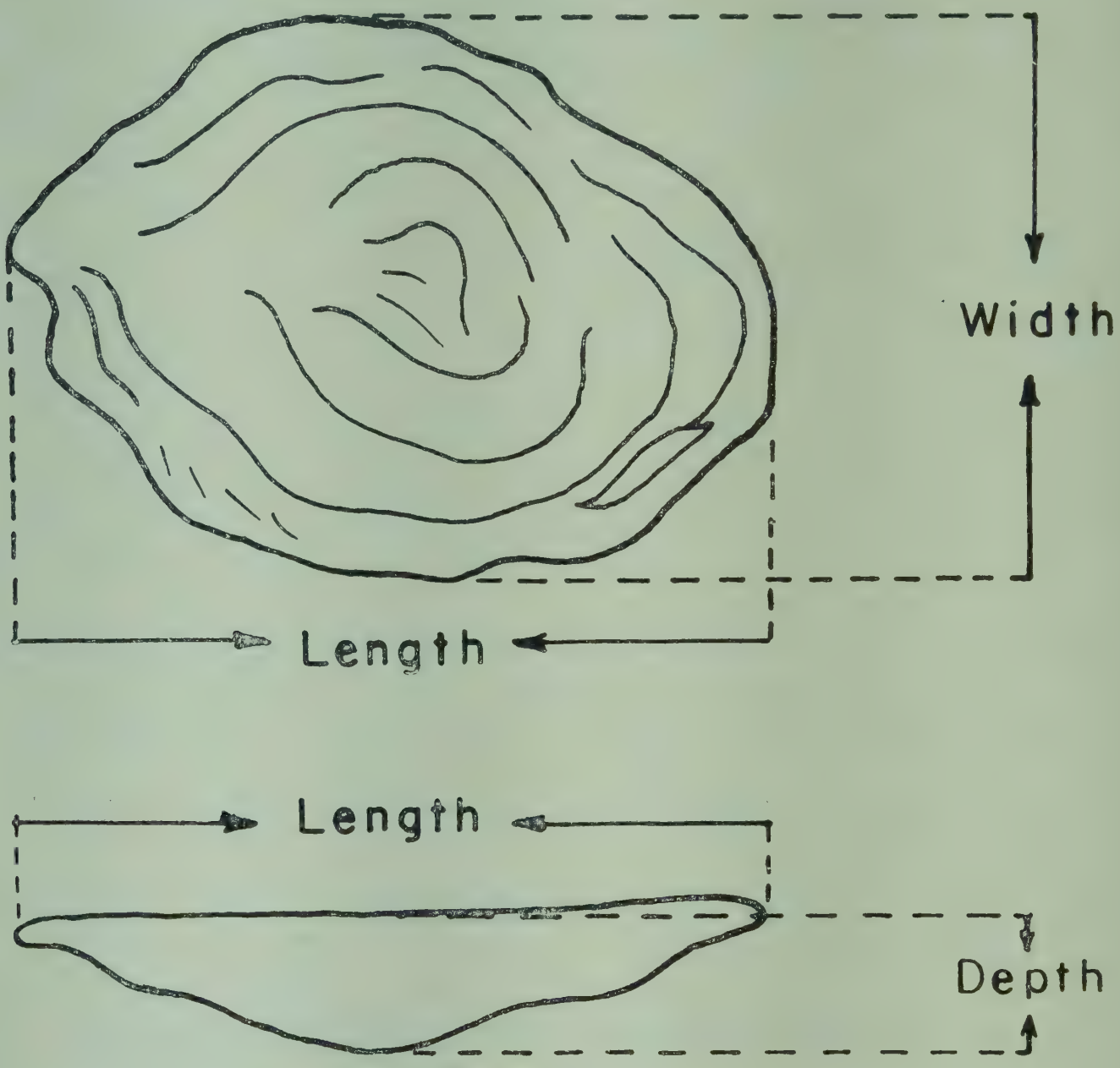

FIGURE 6. - Measurements of shellfish

Crabs. The width of the carapace is the maximum measurement across the carapace, including the spines, if present, at right angles to the median line.

Reference: Cole, H. A. and Mistakidis, M.N. (1953) A device for the quick and accurate measurement of carapace length in prawns and shrimps. *J. Cons. int. Explor. Mer,* 19 (1): 77-79.

Form 4. - Morphometry and life history data sheet

(*a*) Species..... (*b*) Date..... (*c*) Measured by.....

1. Locality					
2. Gear of capture					
3. Weight					
4. Total length					
5. Fork length					
6. Head length					
7. Snout to ins. lst D					
8. Snout to ins. 2nd D					
9. Snout to ins. anal					
10. Snout to ins. ventral					
11. Greatest body depth					
12. Diam. of eye					
13. No. gill rakers					
14. Color					
15. Stomach content — 15.1 Volume					
15. Stomach content — 15.2 Composition					
16. Sex					
17. Degree of maturity					
18. Preserved: Scales					
Gonads					
Vertebrae					
Operculum					
Entire specimen ..					
Other (specify) ..					

19. Remarks: .....

4.4.4 **Morphological measurements and observations**

The measurements and observations described below are usually made for special studies (e.g., racial studies). The measurements vary from family to family of fish and only a few examples are given. In every case the research biologists must give precise instructions concerning the sampling and the accuracy in the measurements.

Notes on Form 4. Morphometry and life history data sheet

This sheet is generally used for single specimens of large species but can also be used with small modifications for groups of specimens sampled. The sheet presented can be used for measurement of five specimens. The methods of measurement are described in Section 3. The measurements Snout to ins. 1st D *et seq.* are the lengths from the snout to the insertion of the respective fins.

14. Describe the color of fish if necessary (e.g. by exotic species).

15. Give the volume of food in stomach and briefly describe its composition.

17. Maturity scale.

18. Indicate the preservations made and give their serial numbers.

19. Make notes on such factors as depth of water, proximity of land, depth of water where caught, etc.

4.4.4.1 Biometrical measurements on clupeoids

Snout to the insertion of the anal fin.

Snout to the insertion of the ventral fin.

Head length - distance from the tip of the snout to the most posterior point of the margin of the subopercle.

Snout to the insertion of the dorsal fin.

For the measurements of sardines the following dimensions have been defined by Ruivo (1957).

Length to the fork (LF), (Zoological length). Distance from the end of the nose to the end of the middle rays of the caudal fork, the fin being flattened out.

Length of the head (LL'). Distance from the end of the nose to the backward bony edge of the operculum (L').

Predorsal distance (LD). Distance from the end of the nose to the forward origin of the dorsal (intersection point of the forward edge of the first ray of the dorsal, D, with the outline of the back, the fin being flattened out).

Prepectoral distance (LP). Distance from the end of the nose to the anterosuperior origin of the pectoral (intersection point of the forward edge of the first ray of the pectoral, P, with outline of the flank, the fin being slightly lifted up).

Preventral distance (LV). Distance from the end of the nose to the anterior origin of the ventral (intersection point of the forward edge of the first ray of the ventral, V, with the contour of the abdomen, the fin being extended).

Preanal distance (LA). Distance from the end of the nose to the forward origin of the anal (intersection point of the forward edge of the first ray of the anal, A, with the outline of the abdomen, the fin being extended).

Maximum height (H). Vertical distance, at right angles to the axis of the fish, between the dorsal and abdominal outline, being measured at the forward origin of the dorsal.

Maximum thickness (E). Thickness of the body measured between the two points of the flank such as are defined by the intersection of the lateral line with a plan perpendicular to the axis of the fish (transversal plan) and passing by the forward origin of the dorsal.

Length of the dorsal (DD'). Distance from the forward origin of the dorsal (D) to the backward edge (intersection point of the backward edge at the last ray, D', with the outline of the back, the fin being extended).

Length of the anal (AA'). Distance from the forward origin of the anal (A) to its backward edge (intersection point of the backward edge of the last ray, A', with the outline of the abdomen, the fin being extended).

Length of the pectoral (PP'). Distance from the anterosuperior origin of the pectoral (P) to the backward end of the longest ray, the pectoral being extended on the side of the fish in its normal position.

Diameter of the eye (OO'). Vertical diameter of the visible part of the eye, i.e., the distance between the upper edge and the lower edge of the orbit.

4.4.4.2 Biometrical measurements on gadoids

(From LeGall, J. (1952) *J. Cons. int. Explor. Mer*, 18 (2): 236-240.)

Snout to insertion of first dorsal: the distance from the tip of the snout to the base of the first ray of the first dorsal.

Length of the first dorsal: measured from the first ray to the posterior extremity of the first dorsal.

Snout to the end of the first dorsal.

Snout to insertion of dorsal: the distance from the tip of the snout to the base of the first ray of the second dorsal.

Length of the second dorsal: measured from the base of the first ray of the second dorsal to the posterior extremity of the second dorsal.

Snout to the end of the second dorsal.

Snout to insertion of third dorsal: the distance from the tip of the snout to the base of the first ray of the third dorsal.

Length of the third dorsal: as for the length of the second dorsal.

Snout to the end of the third dorsal.

Snout to insertion of ventral: the distance from the tip of the snout to the origin of the ventral.

Snout to insertion of anal: the distance from the tip of the snout to the insertion of the first ray of the anal fin.

Length of the anal: measured from the insertion of the first ray to the posterior extremity of the anal fin.

Snout to the end of the anal fin.

Snout to insertion of pectoral: the distance from the tip of the snout to the origin of the first ray of the pectoral fin.

Length of the pectoral: measured from the origin of the first ray to the posterior extremity of the pectoral fin.

Head length: the distance from the tip of the snout to the posterior extremity of the opercle.

Preorbital distance: the distance from the tip of the snout to the anterior margin of the eye.

Postorbital distance: the distance from the tip of the snout to the posterior margin of the eye.

Diameter of the eye.

Greatest depth: measured from the insertion of the first ray of the first dorsal.

NUMERICAL CHARACTERS (ORIGINAL NOTATION)

N1Dr Number of the first dorsal rays.

N2Dr Number of the second dorsal rays.

N3Dr Number of the third dorsal rays.

NAr Number of the anal rays.

NGR Number of gill rakers: observed on the inferior arm of the first branchial arch (anterior of the left side).

NVe Number of the vertebrae: counted after the first cervical vertebrae immediately after the condylus (not counted) till the last caudal vertebrae (urostyle not included).

4.4.4.3 BIOMETRICAL MEASUREMENTS ON TUNAS

(From Marr, J. and Schaefer, M. (1949) Definitions of body dimensions used in describing tunas. *Fish Bull., U.S.*, 51 (47): 241-244.)

Head length: distance from the tip of the snout to the most posterior point of the margin of the subopercle (depressing the fleshy flap extending posteriorly).

Snout to insertion of first dorsal: distance from the tip of the snout to the intersection of the anterior margin of the first dorsal (erected) with the contour of the back.

Snout to insertion of second dorsal: distance from the tip of the snout to the intersection of the anterior margin of the second dorsal (raised) with the contour of the back, marking the point with a scalpel.

Snout to insertion of anal: distance from the tip of the snout to the insertion of the anal (determined as the second dorsal).

Snout to the insertion of ventral: the distance from the tip of the snout to the intersection of the anterior margin of the ventral, when the fin is extended, with the contour of the body.

Greatest depth: the greatest vertical distance between dorsal and ventral contours.

Length of pectoral: the distance from the insertion of the pectoral to the most posterior point, taken with the fin extended posteriorly and opposed to the side.

Pectoral insertion to insertion of first dorsal: the distance from the insertion of the pectoral fin to the insertion of the first dorsal.

Length of base of first dorsal: the distance from the insertion of the first dorsal to the insertion of the second dorsal.

Length of base of second dorsal: the distance from the insertion of the second dorsal to the intersection of the posterior margin of the second dorsal with the contour of the back.

Spread of caudal: the distance between the dorsoposterior extremity of the caudal and the ventroposterior extremity of the caudal. (When caudal fin is not frayed or shrunken.)

Length of longest dorsal spine.

Length of first dorsal spine.

Length of second dorsal: the distance from the insertion of the second dorsal and with the fin in a normal position. Note that the fin is often extended in a long filament and care should be taken to notice if this extension is frayed.

Length of anal: the distance from the insertion of the anal fin to its distal end. Remarks as before.

Length of longest dorsal finlet: the distance from the insertion of the longest dorsal finlet to the end of its posterior filament.

Diameter of iris: the greatest diameter measured to the margin of the yellow iris and the adjoining black tissue.

Length of maxillary: the distance from the tip of the snout to the posterior end of the maxillary.

Least depth of caudal peduncle: the least vertical distance between the dorsal and ventral contours of the caudal peduncle.

Greatest width of caudal peduncle at keels: the greatest horizontal distance between the lateral contours including the keels (not broken or shrunken).

Number of first dorsal spines: the total number of spines discernible with the first dorsal held erect and with no dissection.

Number of dorsal finlets: the number of finlets following the second dorsal and beginning from the caudal and counting separately the finlets attached to the second dorsal.

Number of anal finlets: counted in the same manner as the dorsal finlets.

Number of gill rakers: the number of anterior rakers on the most anterior gill arch on the left side of the fish. The counts of the rakers on the two arms of the arch are kept separate.

Liver: observations on the liver; markings, shape, weight.

4.4.4.4 Biometrical measurements on sharks

Distance from the tip of the snout to the first branchial fissure.

Snout to insertion of first dorsal.

Snout to insertion of second dorsal.

Snout to insertion of anal.

Snout to insertion of ventrals.

Greatest depth.

Length of pectoral.

Height of the first dorsal: note if there is a spine and its length.

Height of the second dorsal: note as before.

Length of the dorsal lobe of the caudal fin.

Length of the ventral lobe of the caudal fin.

Greatest width of the caudal peduncle at keels.

Number of branchial fissures.

Shape of the snout: design.

FORM 5. - MEASUREMENT OF FISH

(*a*) Species ....

(*b*) Date .... (*c*) Locality .... (*d*) Sheet No. ....

(*e*) Vessel, Cruise, Station, etc. ....

(*f*) Gear of capture ....

1		2								
	0									
	1									
	2									
	3									
	4									
	5									
	6									
	7									
	8									
	9									
	0									
	1									
	2									
	3									
	4									
	5									
	6									
	7									
	8									
	9									
	0									
	1									
	2									
	3									
	4									
	5									
	6									
	7									
	8									
	9									
	0									

3. Remarks ....

....

Shape of the teeth: central upper maxillary
lateral upper maxillary
central under maxillary
lateral under maxillary

Distance between the nostrils.

Distance from the tip of the snout and the midst of the line joining the nostrils.

Liver: observations on liver, color and weight.

Denticles of the skin; observed under magnification, and sketched to show their form and disposition.

Notes on Form 5. Measurement of fish

This form is useful for measurement of many specimens of the same species.

(*c*). Give the locality of measurement.

(*e*). Give the name of the vessel and the locality of capture.

1. Use column 1 for lengths. Last digits of the length can be printed and the first digit should be put to suit the length range of fish to be measured.

2. In the columns tick the number of fish in the corresponding length, (e.g. 5 ticks in every column) or use this column for weights if weighing of individual fish is done.

3. Indicate the kind of length measured (e.g. total length, fork length, etc.). Give also remarks on the conditions of measurements and the conditions of fish.

Sometimes filing cards are used for recording fish measurements. One side of the card contains usually the following data: (*a*) species; (*b*) area; (*c*) depth; (*d*) gear; (*e*) vessel; (*f*) locality of landing; (*g*) locality of catch; (*h*) depth of water; (*i*) fishing effort; (*j*) total catch by species, etc.

4.5 WEIGHING

We are concerned here only with weighing individual species for biological purposes, and not at all with weighing catches. The weight of individual fish is required chiefly for the determination of the length-weight relation and condition factors. Weighing of separate organs (e. g., stomach, gonads) is made for various purposes (for determination of the amount of food taken, determination of number of eggs, etc.).

Form 6. - Length-weight data

Lake or Stream .... Date ....

Method of collection .... Collector ....

Species ....

Length	Weight	Sex	Length	Weight	Sex	Length	Weight	Sex	Length	Weight	Sex

The only reliable transportable instruments are steelyards and spring balances. Simple transportable laboratory balances are also useful but the weights with which they are used render them slow in use. Shop balances can also be used in fish markets, if a stable base can be provided and care is taken of them in transport. Spring balances are sensitive to temperature changes and many other factors, but small pocket-size spring balances in various ranges (e.g., 0 - 1 kg and 0 - 10 kg), are useful for rough measurements and should be carried on all trips.

The wetness of the fish should be noted for the weighing to have high accuracy. The biologist must decide on the attention to be given to the effect of differences in the amount of stomach contents and the development of gonads. For some work these organs must be weighed separately.

It is often necessary to weigh butchered fish, i.e., fish whose viscera and/or heads have been removed after capture. In most cases it is desirable to convert the weight of butchered fish to the original live weight. Several conversion tables have been established, for this purpose, by bulk of species, differently butchered, and for different sizes of the same species.

4.6 FIELD EXAMINATION OF GONADS AND EGG COUNTS

4.6.1 **Examination of gonads and maturity stages**

The state of maturity of fish can be determined in field examination. This is usually done by exposing the gonads by opening the ventral cavity.

There are several criteria for the determination of maturity stages, which vary from one group of species to another. However, the following classification of maturity stages can be used for most species (Naier, from Bückmann, 1929).

Stage I — *Virgin*: Very small sexual organs close under the vertebral column. Testis and ovary transparent, colorless to gray. Eggs invisible to naked eye.

Stage II — *Maturing virgin* and *recovering spent*: Testis and ovary translucent, gray-red. Length half, or slightly more than half the length of ventral cavity. Single eggs can be seen with magnifying glass.

Stage III — *Developing*: Testis and ovaries opaque, reddish with blood capillaries. Occupy about half of ventral cavity. Eggs visible to the eye as whitish granular.

Stage IV — *Developed*: Testis reddish-white. No milt drops appear under pressure. Ovary orange-reddish. Eggs clearly discernible; opaque. Testis and ovary occupy about two thirds of central cavity.

Stage V — *Gravid*: Sexual organs filling ventral cavity. Testis white, drops of milt fall with pressure. Eggs completely round, some already translucent and ripe.

Stage VI — *Spawning*: Roe and milt run with slight pressure. Most eggs translucent with few opaque eggs left in ovary.

Stage VII — *Spent*: Not yet fully empty. No opaque eggs left in ovary.

Stage VIII — *Resting*: Testis and ovary empty, red. A few eggs in the state of reabsorption.

Note: Doubful cases are indicated by referring to two stages, e.g., VIII-II, I-II, etc. Stages VII and VIII are sometimes grouped together as stage VII spent.

The gonads should be weighed in fresh condition, because their weight may change considerably when preserved. The counting of eggs can however be done on preserved material. When counting eggs in the field, measure the total displacement volume of the eggs from the ovary in a graduated cylinder. Remove the eggs from the water and count a portion of them.

Measure the displacement volume of the counted eggs and compute the number as follows:

$$\text{Number of eggs} = \frac{\text{total volume of eggs} \times \text{number of eggs counted}}{\text{volume of the counted eggs}}$$

The diameter of fresh eggs may be measured by placing 10-50 eggs in a row, measuring the total length of the row, and dividing by the number in the row.

4.6.2 **Egg counts**

In life history studies and in fish management, the knowledge of the numbers of eggs produced by each species is essential. The number of eggs must be known if survival is to be estimated and the number produced is significant in fish culture in determining the number of fish required for brood stock.

Egg counts can be made in two ways. First, at the time of spawning when the eggs are fully developed and ready to be laid the females can be captured and, with pressure applied to the abdomen, the eggs can be forced from the body into a pan or jar for preservation and enumeration. If it is not necessary to save the female for some other purpose, the female can be killed and cut open and the eggs remaining after the stripping operation can be added to those stripped from her. If the female cannot be killed, then the number of eggs must be considered to be approximate until such time as it is possible to determine the average quantity of eggs remaining after normal stripping operations.

The second method is to remove the entire ovary from the fish prior to full ripening. The closer to the time of full ripening it is possible to obtain the ovaries, the better it is for counting.

The most accurate enumeration of eggs is the actual count, but this can be very tedious and time-consuming. When actual counts become impractical (as in species with very large numbers of eggs) approximate numbers can be obtained by one of the following methods.

VOLUMETRIC METHOD

Under this method there are two ways to make the egg counts. First, count the eggs in a sample of known volume (v) taken from the unknown lot. Such a sample may be measured by water displacement in a finely graduated cylinder and 10 or 20 cc should be adequate. Then measure the total volume (V) of all eggs in the unknown lot. The total number may then be estimated as follows:

$$X : n = V : v$$

where X is total number in the unknown lot
n is number in sample
V is total volume of all the eggs
v is volume in sample

The second method is to count out 100 eggs and measure the volume by water displacement. If the eggs are small, it may be well to count out 200 or even 300 eggs and obtain the volume. Then the entire sample is measured by displacement, and the total number of eggs would be calculated by the formula given above.

GRAVIMETRIC METHOD

In the gravimetric method there are also two ways of computing the number of eggs. First, weigh a definite portion of the sample, such as 1 or 2 grams, and then count the eggs in the sample. Determine the total weight of the whole lot of eggs and calculate on the basis of the sample count.

The second way is to weigh a known number of eggs, and then the total lot, and calculate the total number.

In the gravimetric system it is important to remove the excess moisture. This may be done by placing the eggs on blotting paper for a given length of time, or by spreading the sample in a large pan and allowing the eggs to be exposed to the air for a definite period of time, or in some cases the samples may be placed in a drying oven for a time.

VON BAYER METHOD

In 1910 von Bayer prepared a table for determining the number of eggs per liquid quart based on the diameter of the eggs. A metal trough of known length, usually 150 mm is used. The groove in the trough is filled with a single

row of eggs, and the number of eggs it takes are counted. The diameter of the eggs is determined by dividing 150 mm by the number of eggs. By referring to his chart the number of eggs per quart is found. These values may be changed into number per cc by dividing the number per quart by 946.4 (the number of cc per quart). By determining the number of cc of eggs in the sample by displacement, and multiplying the number found by the number of eggs per cc, the total number of eggs is found. Von Bayer's chart is reprinted in Lagler's *Freshwater fishery biology*.

PRESERVED OVARIES

When it is necessary to make counts from preserved ovaries, the following method may be used.

Measure the total volume of the ovaries by water displacement. Then obtain volumes of each of three sections, well-spaced, from the ovary. Separate out and count the mature eggs from each ovary section, separating them from the immature eggs and tissues. Take the volume of immature eggs and tissues and subtract from the volume of the sections to get the volume of the mature eggs. Take the average results of three (or sometimes more) counts and compute the number of fully developed eggs per cc and then for the complete ovary.

The count can also be made using the gravimetric method by weighing three samples from various parts of the ovary, counting the eggs as described above, and calculating the total numbers on a basis of weight instead of volume.

4.7 EXAMINATION AND ANALYSES OF STOMACH CONTENT

4.7.1 **Field examination of stomachs**

In a field examination of stomachs the following preliminary notations are used.

(*a*) *Degree of fullness.* Full, half full, nearly empty, empty.

(*b*) *Degree of digestion.* Fresh, half digested, digested.

(*c*) *Type of food in the stomach.* Give the identifiable species or groups of species and estimate their relative abundance (e.g., fish larvae 50%; Euphausids 25%; unidentified 25%).

(*d*) *Stage of the fish* (mainly applicable for Clupeoids).

1° Lean; no traces of fat in the digestive tube.

2° Not very fat; a string of fat not thicker than 1 mm along the digestive tube.

4° Very fat; the digestive tube is completely enveloped by fat.

Exact volumetric measurements of stomach contents and detailed identification of food species found in the stomach are usually carried out in the laboratory.

4.7.2 Stomach analyses

4.7.2.1 Processing of stomach content

The processing and analysis of stomach content of marine and freshwater fish are essentially the same. In the following pages are given instructions which apply strictly to fresh-water species and with slight modifications, also to marine species.

CARNIVOROUS OR OMNIVOROUS SPECIES

1. Remove from the formalin jars the number of packets which can be completed in a regular work period and soak in water for 24 hours. This will remove most of the unpleasantness of the formalin. Caution must be used not to leave samples in water longer than 48 hours or they will start deteriorating. A deformalizing solution also can be used very satisfactorily.

2. Place individual digestive tract in a Petri dish or other suitable container and remove all foreign matter (fat, liver, pancreas, etc.).

3. Remove stomach, cut open, flush out organisms with bulb syringe or wash bottle. Some particles may still adhere to stomach walls and these should be picked carefully with forceps. Use as little water as possible in washing out contents.

4. Examine contents under dissecting microscope; separate, identify and enumerate organisms present.

5. Place the individual organisms or groups of organisms on a blotter for not more than one minute to remove excess moisture.

6. After this brief drying, place the various individuals or group of individuals in a centrifuge tube containing 5 cc of water and record volume displacement for each.

7. Compute the percentage of total volume of each organism or group present.

8. If there is a large amount of plankton present, pour sample into centrifuge tube and allow to settle for 15 minutes. Record the volume of plankton. Then dilute to 5 or 10 cc and gently mix concentrate by inverting tube several times. With a 1-cc wide-mouth pipette immediately remove sample before plankters settle, and fill a Sedgwick-Rafter cell as for plankton analysis. Count organisms and multiply by dilution and record total numbers.

9. When the volume of any organism is less than 0.1 cc record as T for trace.

10. Use symbol $<$ 0.1 cc for less than 0.1 cc in grand total.

11. Fish found in stomachs should be identified if possible. Also measure to the nearest millimeter if whole.

12. A record sheet should be made out for each stomach examined, even if empty.

13. Under comments include such information as: kind and number of parasites found, abundance of winter or summer eggs of copepods, etc.

14. Preserve and label any organism not previously found.

15. Stomach contents are identifiable or not. Do not clutter up record form with question marks.

LABORATORY ANALYSIS FOR HERBIVOROUS SPECIES

1. Remove packets as in 1 above.

2. Same as 2 above.

3. Obtain a 2 cc sample from the most anterior part of the intestine. In some cases the entire contents of the whole intestine will be needed and the sample will still not equal 2 cc.

4. Place 2 cc or entire sample if less than 2 cc in a centrifuge tube. Some packing may be necessary to remove air bubbles. A gentle stirring with a teasing needle should be sufficient for the purpose.

5. If a 2 cc sample is obtained, dilute to 10 cc level. Stir and shake to break up any large clumps of some forms. If less than 2 cc is obtained, dilute proportionately. For example, if a 1 cc sample is obtained, dilute to 5 cc; if 1.5 is had, dilute to 7.5 cc, etc. This will give a constant dilution of the concentrate.

Form 7. - Fish stomach record

Species .....
Length ..... Weight ..... Sex ..... Date .....
Determined by .....

Organism	No. of spec.	No. of indiv.	Vol. in cc	% tot. vol.	Organism	No. of spec.	No. of indiv.	Vol. in cc	% tot. vol.
Annelida					Hemiptera				
Mollusca					Coleoptera				
Entomostraca					Lepidoptera				
Malacostraca					Diptera				
Aquatic insects					Hymenoptera				
Ephemeroptera									
Odonata					Total volume				
Plecoptera					Fish				
Hemiptera									
Coleoptera									
Trichoptera					Amphibians				
Diptera					Algae				
Arachnida					Higher plants				
					Debris				
Total volume					Inorganic				
Terrestrial insects					Plant				
Collembola					Animal				
Orthoptera									
Neuroptera					Grand total				
Homoptera									

A - Adult, N - Nymph, P - Pupa, L - Larvae

6. With a 1-cc wide-mouth pipette remove a 1 cc sample and place in a Sedgwick-Rafter cell as for plankton analysis, count organisms and multiply by dilution and record total number on record form.

7. Occasionally large clumps of algae and other vegetable matter will be ingested. Estimate the percentage by volume this material makes up of the total and remove from sample and follow above procedure. This food material which cannot be counted should be considered separately and given only a percentage basis. Other countable items are expressed in percentage by numbers. Thus the sum of the percentage items counted will total 100 percent. For example, a carp sample was made up of 50 percent algal mass and 50 percent countable forms. Of the countable forms, cladocerans made up 90 percent and copepods 10 percent.

8. Stomach contents are either identifiable or not. Do not clutter up record form with question marks.

4.7.2.2 Specification of gut contents

The following outline of methods is based mainly on the review by Hynes, H.B.N. (1950) The food of fresh-water sticklebacks. *J. Anim. Ecol.*, 19 (1) : 35-58. The term *food item* is not intended to refer to a species; it may be a taxonomically heterogeneous group classed together by some other common attribute. It should be borne in mind by interpretation of the results that the method of catch has an influence on the stomach content.

1. *Occurrence method*

   (*a*) The number of fish in which each food item occurs is given as a percentage of the total number of fish examined.

   (*b*) The total number of occurrence of all items is summed, scaled down to give percentage composition of diet. The importance of small numbers and small food items is magnified with this method.

2. *Number method*

   (*a*) The total numbers of individuals of each food item are listed.

   (*b*) Expressed as a percentage of total number of organisms in all fish (not applicable to vegetable food, etc.). Small food items magnified in importance.

3. *Dominance method*

   The number of fish in which each food item occurs as the dominant, expressed as in 1(*a*) and 1(*b*).

4. *Volume and weight methods*

(*a*) The volume or weight of each food item of total food in each fish is given as percentage of weight of fish. The volume of each item may be estimated or measured.

(*b*) As 4 (*a*), but counts of food organisms are multiplied by the known average weights of individuals of each item.
Mean index of feeding $= v.10^5/1^3$ where v = displacement volume of stomach contents and 1 = body length (see Iizuka *et al.*, 1954). This is an accurate method, but occasionally large items cause an incorrect picture of their real importance.

5. *Fullness method*

Estimate the degree of fullness of each gut by a ranking or points system. This is really a form of 4. The accuracy of this method depends on individual experience.

6. *Points method*

Each item in each gut is graded as "common," "frequent," etc., with allowance for the size of the organism as well as its abundance (one large is treated as equivalent to many small). Give rank numbers or points for each category, sum and scale to percentage of total. This is essentially volumetric. It is rapid, easy, and requires no special apparatus; it may be modified by taking fullness also into account, and does not give a spurious impression of accuracy.

4.8 AGE DETERMINATION AND SCALE MEASURING

Age determination is one of the most important analyses of fish and has many uses in fisheries research. There are various methods for age determination. One of the simplest but least accurate is the estimation from the length-frequency distribution. This method is not possible with older fish and often gives misleading values also with younger ones. The other possibility is the use of otoliths, spines, rays, vertebrae and scales, which usually, but not always, have marked annual rings. In most cases when scales cannot be used, otoliths are useful. The sagitta or sacculolith from the sacculus of the inner ear is used. In some cases it is necessary to polish the otolith or to break a bigger one. From spines and rays, thin cross-sections are used as well, as from vertebrae where one of the five first prehaemals is taken.

The scales are usually the most trustworthy for age determination when they can be used. However, there are certain irregularities caused both by "checks" and regeneration. Different species have certain peculiarities in the scales which must be learned from practice.

As dried scales are usually used, they must first be soaked and cleaned of adhering fat and mucus. They can be left to rot a few days in a small volume of water and are then washed in peroxide or in 5% KOH. Temporary or permanent amounts can be made, using euparol, glycerin-gelatine and gum arabic. Several scales of the same fish are mounted on one slide.

By counting the true annual rays, the scales can also be used for back computation of the length of the fish at different ages, because there is usually a good relation between the scale measures and growth of fish. Appropriate graphs should be constructed for every species, as the relations between scale measures and fish growth vary slightly from species to species. The scales are measured either on special projection apparatus using a simple slide projector or by use of a microscope's drawing apparatus.

If the age determination, using scales, bones, etc., is impossible, the size-frequency curves are used for the estimation of probable age.

4.9 OBSERVATIONS ON FISH DISEASES AND MORTALITY: PARASITE EXAMINATION

4.9.1 **Field observations on fish diseases and mortality**

All fish which have symptoms of disease should be preserved for laboratory study. This is especially necessary if abnormal mortality of fish is observed. Before preservation, a field examination and description should be made. This examination should include notation of: (1) Gills; color, whether gill lock and mouth are open, presence of parasites, algal growth or mud on gills, etc.; (2) Color of the fish body, discoloration, etc.; (3) External damage of the body; (4) Discoloration or malformation of liver, stomach, etc.

Only dying or recently dead fish may be preserved for further laboratory study.

When mass mortality of fish is observed, the environment should be described in the fullest possible detail. Note especially the winds and currents at the time of the observation and for the previous days. If proper hydrographic survey work cannot be undertaken, water should be sampled; at each station three 1-liter bottles of water should be taken, one unpreserved and one should be preserved with hydrochloric acid (about 7.5 ml; 12 normal HCl per liter) and the other with formalin to get approximately a 2% solution of formalin. It is advisable, if possible, to take samples at several places and at several depths, especially upcurrent and upwind of the place where the dead fish occur. Plankton samples should also be collected. The samples should be sent to the laboratory for analysis as soon as possible.

4.9.2 **Parasite examination**

The parasite examination is of great importance, especially on fresh-water species. Also on marine species they can serve various purposes, e.g., for identification of stocks, etc.

A parasite examination record sheet should be made out for each important fish species of the water studied. Identification of some of the more common parasites can be made in the field. Specimens of those and of the less common or unusual forms should be preserved for laboratory examination. Kill and fix the specimens in Bouin's solution, then preserve in 70% alcohol. Be sure to label completely.

Fill out the record sheet completely. Fill in every blank either with the kind and number of parasites found, or with NONE if none were found. If the organ or area is not examined draw a line through the blank to so indicate.

Form 8. - Parasite record

Lake or Stream .....

Species ..... Length ..... Weight ..... Sex .....

Skin ..... Pectoral: Fins .....

Pelvic ..... Dorsal ..... Anal ..... Caudal .....

Gills ..... Mouth cavity .....

Orbit ..... Eyeball .....

General musculature .....

Stomach ..... Pyloric caecae .....

Rectum ..... Intestine .....

Peritoneal cavity ..... Liver .....

Gall bladder ..... Kidney .....

Air bladder ..... Testes, Ovaries .....

Pericardial region ..... Stomach surface .....

Intestine surface ..... Fresh or ..... Preserved specimen .....

Examined by ..... How taken? .....

Form 9. - Labeling of collections

(1) The labels should be made of suitable material (e.g., linen) so that they can be put into the preservative together with the specimens. The writing on these labels should be done with an indelible pencil. Gummed labels should not be used on the outside of jars. The labels should be tied on. An example of the data needed on a label follows:

Index ..... *Species* .....

Date ..... *Time* .....

Locality .....

Measures .....

Gear ..... *Depth* .....

Observer, Collector ..... *Vessel and Station No.* .....

Log .....

(2) *Index* Indicate with proper codes whether it is plankton, fish stomach, etc.

(3) *Measures* e.g., displacement volume of plankton, total length of fish, etc.; always indicate what has been measured.

(4) *Gear* The gear or method of capture.

(5) *Log* Indicate in which logs the notes on preservation are made.

4.10 TAGGING OF FISH

The purpose of tagging operations is to obtain information on

1. Migrations
2. Fishing mortality
3. Growth.

The planning of these operations involves decisions on the size range of the fish to be tagged, places and times of tagging, numbers of fish to be tagged at each tagging occasion and in the entire program, and methods to be adopted to obtain delivery of recovered tags and tagged fish. These decisions are made

in the light of what is already known of the biology of the species under investigation, and with reference to the problems to be studied and to technical aspects of the operations. At the planning stage consideration must be given also to the following factors which affect the results of tagging experiments.

1. Method of capture and handling of fish prior to tagging.

2. Handling of fish during tagging and its effects on tagging mortality.

3. Tag characteristics in respect of the characteristics and behavior of given species and in respect of recovery of tags.

4. Methods of recapture in respect of types of fishing gear, tags and location of fishing areas, and possibilities of complete reporting of necessary data by fishermen upon recovery of tagged fish.

The technical questions concern the choice of tag, the methods of capturing, handling and releasing the fish. The whole subject will be dealt with in detail in a special manual. Reference is made to an excellent summary on the subject by Rounsefell and Kask (1945).

4.11 INVESTIGATIONS ON FISH EGGS AND LARVAE

Fish eggs and larvae are collected together with the plankton by the methods described in Section 3.

Buoyant eggs of coastal spawning fish are often washed ashore and can be collected on tide marks or in wave wash. Eggs on the bottom are gathered with bottom egg nets which are equipped with a scraper which scratches the eggs loose and leads them into the bag; or a special highspeed trawl is used, which also catches small vagile benthos organisms, such as Harpacticoids, etc.

One of the special applied investigations of plankton samples is that of the identification and enumeration of fish eggs and larvae. Usually, the plankton samples for this purpose are collected with so-called "egg nets" and the collection must be quantitative in order to be able to compute the amount of fish eggs released at a given time and area, which often gives a good measure of the size of the spawning stock of a particular species. In some cases in the early stage of fisheries investigations in certain areas the egg counts are used for determination of the spawning areas and times of certain fish species.

For the identification of the eggs and larvae a special synopsis will be prepared by Fisheries Biology Branch. Laboratories have to collect the descriptions of the eggs and the developmental stage of the larvae of their interest and make type collections of them if necessary. It is often advisable to pick out the fish eggs and larvae before preserving the plankton catch and to let the eggs develop in small volumes of water of the same origin and tempera-

ture. In this way, identification can be established with greater accuracy. The eggs are sorted out in large Petri dishes (diameter 30 cm). It should be borne in mind that during preservation, the pigment often changes.

For the identification of the eggs various criteria should be used, e.g., diameter of the eggs and pigmentation, the shape of germinative disks, etc. During the counting, the eggs are usually classified into the following five developmental stages.

1. U Undeveloped
2. G Germinative disk
3. yE Young embryo
4. pE Embryo with distinct pigment
5. pO Embryo with pigmented eye

4.12 EXPLANATION OF TERMS

ALLOMETRY. Change of size (measures).

CALIPER. A graduated rod or rule with one fixed and one sliding jaw.

CARAPACE. A bony or horny case or shield covering the back or part of the back of certain animals.

CAUDAL FIN. Tail fin.

CONDYLUS. Knuckle, joint.

CUBE ROOT. Root of a tropical American plant furnishing rotenone.

DENTICLE. A small tooth.

DEPTH OF THERMOCLINE. Depth from surface to the upper boundary of sudden temperature change with depth (depth of the mixed surface layer).

DORSAL. Pertaining to, or situated near or on the back.

FACE MASK. Mask used in diving in shallow water.

IRIS. The opaque contractile diaphrahm perforated by the pupil and forming the colored portion of the eye.

LATERAL. Of or pertaining to the side.

MAXILLARY. Of, pertaining to, or designating a jaw.

OTOLITH. Ear stone, a calcareous concretion in the internal ear.

PECTORAL. Of, pertaining to, situated or occurring in or on the breast or chest.

PEDUNCLE. A stem or stalk.

PHOTOTAXIS. A taxis (movement) in which light is the directive factor.

REGENERATED SCALE. Scales of fish where the rings have disappeared in part (being absorbed and/or dissolved).

ROSTRUM. A part suggesting an animal's beak.

VAGILE. Mobile (animals with ability to move).

VARIANCE. Degree of variation, deviation.

VENTRAL. Designating, pertaining to or situated on the belly (or lower surface of the body).

4.13 REFERENCES

ANON. Modern fish detecting equipment. *Norweg. Fish. News*, 6 (2): 13-15. 1959

BÜCKMANN, A. Die Methodik fischereibiologischer Untersuchungen an Meeres- 1929 fischen. Abderhalden, *Handbuch der biologischen Arbeitsmethoden*, 9 (6,1). Berlin, Urban und Schwarzenberg. 194 p.

GERHARDSEN, T.S. Echo ranging for Norwegian herring. *World Fish.*, 8 (11): 1959 20-22.

HOLM, W.T. A simple method for increasing contrast in scale reading. *Trans.* 1959 *Amer. Fish. Soc.*, 88 (4): 356.

LAGLER, K.F. *Freshwater fishery biology*. Dubuque, Iowa, Brown. 421 p. 1956

MARCHAND, J.M. Standard methods of sampling and examination. *In* South 1950 Africa. Division of Fisheries. *Twenty-second annual report for the year ended December 1950*, p. 19-25.

MARR, J.C. *Marine fishery biology*. Santiago, Chile, FAO Regional Office. 1952 (Mimeo)

PARRISH, B.B., JONES, R. & POPE J.A. A comparison of mesh-measuring 1956 methods. *J. Cons. int. Explor. Mer*, 21: 310-318.

ROUNSEFELL, G.A. & KASK, J.L. How to mark fish! *Trans. Amer. Fish.* 1945 *Soc.*, 73: 320-363.

ROUNSEFELL, G.A. & EVERHART, W.H. *Fisheries science: its methods and* 1953 *applications*. New York, Wiley. 444 p.

U.S. FISH AND WILDLIFE SERVICE. PACIFIC OCEANIC FISHERY INVESTIGATIONS. 1953-54 *Scientific field manual*. Washington, D.C. (Mimeo)

Price: $0.50 or 2s 6d

15615/8.65/E/1/3800